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ON ATMOSPHERIC CONDITIONS REQUIRED FOR ASTRONOMICAL OBSERVATION.

By W. W. Campbell.

The importance of good atmospheric and general conditions for astronomical research has probably been realized by every observing astronomer since the days of Sir Isaac Newton. Newton called attention to the important fact that however perfect a telescope may be there yet remain certain limitations to its performance, arising from imperfections in the atmosphere thru which the observer looks. Newton commented that the only remedy is "a serene and quiet air, such as may perhaps be found on the tops of the highest mountains above the grosser clouds." I have for many years ardently admired Newton's use of the word "perhaps" in this connection.

Notwithstanding the value which astronomers in general have for many generations placed upon good conditions, they have been obliged to accept conditions as they exist near the cities and universities with which their life has been associated, with only a few exceptions, almost up to the present generation of astronomical workers. There was the expedition of Piazzi-Smyth to the Peak of Teneriffe, principally to answer the question, "How much can astronomical observation be benefited by eliminating the lower part of the atmosphere?" Green went to Madeira in 1877 to observe *Mars,* partly because of more tranquil atmosphere than at his home station, and partly to have *Mars* transit the meridian at a greater altitude. Tacchini constructed an observatory on Mount Etna. Janssen's observatory on the summit of Mount Blanc was a heroic effort for better atmospheric conditions. Langley conducted a notable expedition to Mt. Whitney, and there have been several similar undertakings. Strenuous efforts were made to induce JAMES LICK to locate his observatory in the Sierra Nevada Mountains, at an altitude not less than 10,000 feet, but other counsel persuaded him to select an altitude of only 4,200 feet. Many other observatories have in recent years been located on the summits of mountains or on plateaus. The most extensive tests at prospective observing stations have been made by the Harvard College Observatory, notably by Professors BAILEY and WILLIAM H. PICKERING on the west coast of South America, by Professor BAILEY in South Africa, and by Professor PICKERING in Mexico, Southern California, Arizona and the West Indian Islands. COPELAND in the early 1880's tested many stations in the high equatorial regions of South America. Eclipse observers have reported upon conditions at a multitude of widely distributed stations occupied by their expeditions. Messrs. WRIGHT and CURTIS, when successively in charge of the D. O. Mills Expedition to the southern hemisphere, made careful tests of many places in Central Chile, thruout a range of several degrees of latitude. Under the auspices of the Carnegie Institution, Professor HUSSEY tested the conditions existing at several promising stations in Southern California, Arizona, and Australia. Many observers have thought that the best conditions could perhaps be found on some of the small tropical islands, tho the reports by eclipse observers are somewhat conflicting as to the merits of an insular location, and the experience of Sir DAVID GILL on Ascension Island was not favorable. In *The Observatory,* Vol. 36, pages 401-404, Professor WILLIAM H. PICKERING made a strong plea for the tropical island, as a result of his experiences at Mandeville, Jamaica, at an altitude of 2,100 feet above sea-level, with an 11-inch refractor. The disadvantage of the usual enervating effects of tropical climate is readily avoided, he says, by ascending to a moderate altitude. He claims for his station a larger proportion of clear nights than exist in the eastern part of the United States or in the temperate zone generally, clearer sky, greater freedom from night winds, a command of a larger area of the heavens, greater personal comfort of the observer, and, most important of all, the better definition of the objects observed. The best "seeing" at Harvard Observatory ranges from 6.2 to 6.5 on the scale of 10 for perfection, whereas at Mandeville it reaches 8.8. The steadiness and definition of stellar images for objects within 30° of the horizon at Mandeville is as good as the steadiness and definition of objects within 30° of the zenith at Harvard. He states that the terminator of the Moon as viewed with a power of 350 diameters is absolutely sharp, without the slightest perceptible motion or vibration, on one night in three on the average thruout the year. To quote his very strong sentence on the subject: "Under these circumstances it would appear that we are seeing the Moon as clearly as we should if our own atmosphere were entirely removed." Many experienced observers will naturally look twice at the quoted sentence, because of the superlative degree employed therein.

Professor PICKERING'S explanation of the better conditions existing in the tropics is based upon HAHN'S conclusion that the great anti-cyclones which sweep the temperate zones, mixing the air of different strata, are more frequent in the United States than in any other portion of the world. These, in his opinion, are the source of the disasters to astronomical definition. He says: "It is doubtful if any portion of the civilized world can furnish poorer seeing than is usually found in our Eastern States," whereas the anti-cyclones reach down to the tropics only once in a great while. Professor PICKERING'S opinion is "that in the future many of the large observatories of the world will maintain tropical sub-stations, furnished with instrumental equipments of the very finest quality, and that from these stations most of the world's observing will ultimately be done." The opinion of many astronomers has long been to the effect that such tropical locations as Professor PICKERING describes must have great merit, and they have examined the map of the world with longings to make tests on certain tropical islands.

Professor PICKERING does not comment upon the Jamaican conditions for observations of the Sun.

It had seemed to many that the Kodaikanal Observatory, near the southern point of India, latitude 10° north, should possess excellent observing conditions. The mountain peak upon which the observatory stands has a large and relatively flat top, altitude 7,700 feet, and the instruments are not near any steep slopes. The excellent results which flow from the Kodaikanal Observatory are assurance that the combination of observers, instruments and observing conditions has a high mean value.

Bulletin No. 42, recently issued by the Kodaikanal Observatory, calls attention to the fact that the atmospheric conditions at that station, at least for solar observations, are extremely poor in comparison with the conditions which Director EVERSHED has found to exist on the floor of the Kashmir Valley, in the north temperate zone, latitude 34°. The floor of the Kashmir Valley is 5,200 feet above sea-level, and is some 15 or 20 miles wide by about 80 miles long. The valley is completely surrounded by high mountains, ranging from 15,000 feet above sea-level on the southwest side to more than 20,000 feet on the north and northeast sides. In August and October, 1913, and again in May, June, and July, 1914, extensive atmospheric tests were conducted in the vicinity of Srinagar, on the floor of the valley. In 1914, both before and while the Kashmir tests were under way, comparative observations were made at Kodaikanal. The superiority of the conditions in the Kashmir Valley was strongly marked. At Kodaikanal, as at many other mountain observatories, solar observations have generally to cease when the morning Sun reaches an altitude of 25° or 30°, because the images become extremely unsteady. In the Kashmir Valley, on the contrary, the solar images were excellent to start with and retained their excellence thruout the day. Several stations were occupied in the floor of the Kashmir Valley, and a few observations were made at selected points on the mountain slopes surrounding the valley. The day-time atmospheric conditions in the valley were notably superior to those at the higher altitudes. The best conditions in the valley were at a station surrounded by lakes and flooded rice fields. The night conditions on the slopes were better than the day conditions, but not so good as the night conditions in the valley.

The number of hours of sunshine at Kodaikanal and Srinagar are shown by the records to be practically the same, 2,028 hours per annum. EVERSHED estimates, "that at Kodaikanal not more than one hour in six of bright sunshine is available for photography, or for detailed spectrographic study, because of unsteady solar images, whilst in Kashmir at least five hours out of six would be available—a very conservative estimate would give four times the opportunity for work in Kashmir as compared with Kodaikanal, and in addition the quality of the material which could be secured at all times in Kashmir would be equal to the very best that Kodaikanal can produce on occasions when the definition is really good."

EVERSHED's atmospheric tests in New Zealand have led him to select the summit of a low hill near the coast line for the site of the Cawthorn Observatory. The definition on the higher hills in the same neighborhood, so far as solar observations were concerned, were poorer than on the low hills. I understand that Mr. EVERSHED regards the tropics as unfavorable for observations of the Sun. Director EVERSHED's paper does not describe the *night* conditions existing at Kodaikanal. A full report on this subject would be read with great interest.

It should be said that many conditions, atmospheric and general, concern the advantageous location of an observatory. Much depends upon the nature of the observatory's program, and something upon the size of the instruments to be employed. The heavy deposit of dew which characterizes tropical stations in general may not be important with small instruments, but it might be very serious with large refractors or large reflectors. This point has not been adequately tested. The clouds come quickly and go quickly in the tropics. This factor is comparatively unimportant when the equipment consists of a small telescope, and the observations are visual or involve only short photographic exposures; but it would be extremely serious for a large institution whose observations are principally photographic, and especially so if the exposures are long. In the first case the observer can open his dome quickly and proceed at once with his observations; in the latter case a couple of hours in the late afternoon may be spent in getting the extensive instrumental equipment ready for observation, and clouds may render his preparations useless, or he may be in the midst of a three-hour exposure when the clouds compel him to cease observing and to throw away the partially-exposed plate. One of the valued conditions on Mount Hamilton is that the nights are in general entirely clear thruout their whole duration, or are entirely cloudy thruout their whole duration. When clouds do arrive in the course of the night they frequently render absolutely useless many hours of hard work devoted to the adjustments and to the first part of the exposure necessary to give the photographic image the desired intensity. The administration of a great observatory with fair economy and efficiency depends not only upon atmospheric conditions but upon general conditions. I can conceive of no plan so inefficient and unwise as that of locating a permanent observatory on a high mountain peak, such as Mount Whitney or Mont Blanc. Such a location would be practically useless during the large majority of the months of the year, and the connections of such an observatory with the outside world, maintained at great risk year after year, would sooner or later involve tragedies not justified by the scientific results.

ASTRONOMICAL OBSERVATIONS IN 1914.

Made by Torvald Köhl, at Odder, Denmark.

Variable Stars.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris*.[1]

Jan. 17: S 2 steps < e.
Feb. 4: = d.
17: 1 step < d.
27: 4 steps > d.
Mar. 4: = d.
16: 1 step > d.
24: 2 steps > d.
29: 4 steps < c.
Apr. 16: 5 steps > d.
May 24: 2 steps < e.
28: id.
Aug. 16: = f.
18: id.
22: 4 steps < e.
Aug. 24: 2 steps < e.
27: 4 steps < e.
31: 3 steps < e.
Sept. 6: 1 step < e.
11: ½ step < e.
12: = e.
15: id.
19: 1 step < d.
20: ½ step < d.
23: = e.
29: ½ step > e.
Oct. 2: 1 step > d.
4: id.
12: = d.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 73, **12**, 56.